FREQUENCY SYNTHESIZER FOR A 27-MHz CITIZENS' BAND TRANCEIVER

by Larry Blaser

INTRODUCTION

The class-C 23-voice channels in the 27-MHz citizens' band are located at 10-KHz intervals from 26.965 MHz through 27.255 MHz; except for several 10-KHz skips and one 20-KHz skip. This regularity in spacing makes it possible to synthesize the transmitter frequencies of an all-channel citizens' band transceiver using fewer than the 23 crystals required if each channel were individually crystal-controlled. Also, the additional 23 local oscillator frequencies needed in the receiver section of the transceiver can be synthesized.

This paper describes a three-crystal frequency synthesizer which develops the 46 (twice 23) frequencies required in an all-channel citizens' band transceiver.

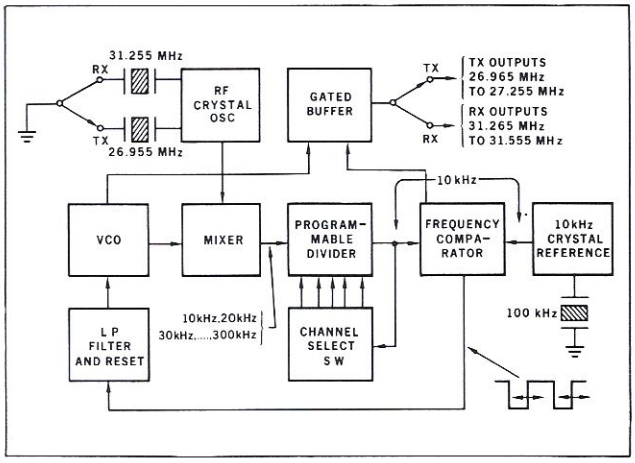

Fig. 1. Block diagram of frequency synthesizer.

FREQUENCY SYNTHESIZER

Table 1 lists the transmit frequencies and the necessary local oscillator frequencies for a commonly used 4.3-MHz first IF amplifier. Local oscillator frequencies for any other first IF frequency could just as easily be synthesized. The significance of the information listed in other columns of Table 1 will become apparent in the discussions which follow.

A block diagram of the frequency synthesizer is shown in Fig. 1. The synthesizer outputs serve as the transceiver RF oscillator signal in transmit operation and as the local oscillator signal in receive operation. They are taken from the voltage-controlled oscillator (VCO) through a gated buffer stage. The VCO frequency is voltage-controlled by the filtered output of the frequency comparator. Two inputs are supplied to the frequency comparator: one, a 10 KHz reference (standard) signal originating from a 100 KHz crystal-controlled oscillator and the second, the output (tachometer) signal from the programmable divider. The input to the divider is taken from the mixer, which develops and passes the difference frequency signal between the VCO and the RF crystal-controlled reference oscillator.

As a stabilized, closed-loop system, the VCO operates above the frequency of the RF reference oscillator. The difference frequency from the mixer is divided down to the tachometer frequency, which is equal to the standard frequency (10 KHz).

The divider is programmable from divide-by-1 through divide-by-30, with certain omissions which correspond to

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the skips in the spacing of the citizens' band class-C voice channels. The complete divider program is given in Table 1.

A divide-by-1 program requires a 10-KHz input to the divider. Depending on the mode of operation, the VCO will oscillate at either 26.965 MHz (Channel 1) or 31.265 MHz (Channel 1 local oscillator), since these frequencies are each 10 KHz above the RF reference frequencies for transmit and receive: 26.955 MHz and 31.555 MHz, respectively. Dividing by greater than 1 will increase the frequency of the VCO. For example, the divide-by-30 program requires a 300-KHz difference frequency which is developed when the VCO operates at 27.255 MHz (Channel 23) in transmit and 31.555 MHz (Channel 23 local oscillator) in receive.

The frequency comparator has a V+ control voltage output when the tachometer frequency (output of the divider) is below the standard frequency, and zero when it is above. When the tachometer frequency is equal to the standard frequency, the control voltage output switches between zero and V+ at the input frequency rate. The duty cycle of the output waveform depends on the phasing of the two inputs.

A second output from the frequency comparator is a gate voltage which keeps the buffer stage turned off until the synthesizer has stabilized, thereby blocking extraneous frequencies generated by the VCO during either turn-on, mode switching, or channel selection.

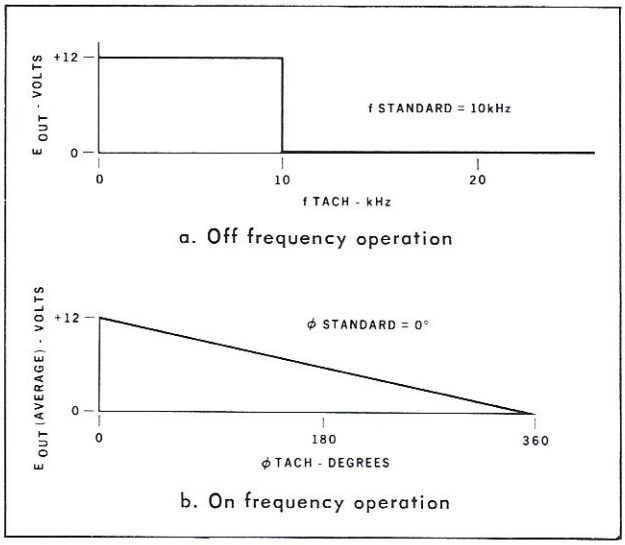

Fig. 2. Frequency comparator output.

Fig. 2 graphically illustrates the operation of the frequency comparator for both "on" and "off" frequency operation.

At this point, it can be seen that the frequency of the VCO must increase with a positively increasing control voltage for the VCO to lock in at a frequency above the RF reference. The frequency of the VCO and the output of the mixer versus VCO control voltage is shown in Fig. 3 for transmit operation of the synthesizer. Except for a 4.3-MHz shift of the RF frequencies, receive operation of the synthesizer is identical to transmit operation. If, during either turn-on, mode switching, or channel selection, the VCO becomes lower in frequency than the RF reference by an amount which would develop a divided difference greater than the 10-KHz standard frequency, the comparator output would be low and the VCO would not lock in. The reset prevents this by switching the control voltage to V+ and then allowing the control voltage to sweep the VCO from a higher than normal frequency back down to a lock in condition.

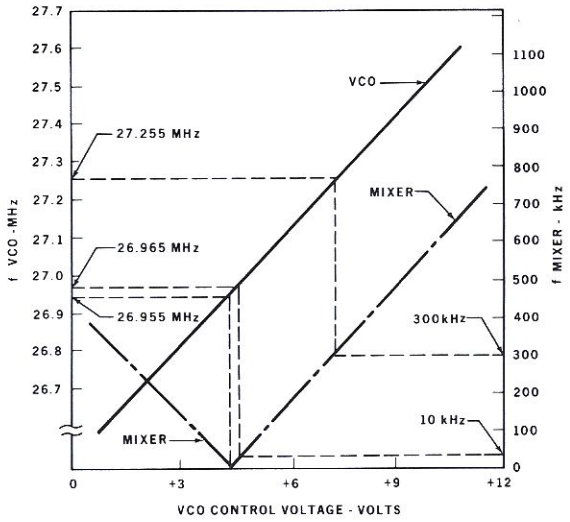

Fig. 3. VCO and mixer output frequencies versus VCO control voltage.

CIRCUIT DESCRIPTION

The complete synthesizer, shown schematically in Fig. 4, is broken into sections which correspond to the blocks in Fig. 1.

Both the crystal-controlled RF reference oscillator and the VCO use and NPN transistor, SE5025, connected in the common-base configuration. Feed-back is taken from the collector to the emitter through a capacitive divider, which is part of the collector tuning. The frequency of the RF reference oscillator is accurately controlled by the crystal which bypasses the base to ground at the series resonate frequency of the crystal. The collector tank is tuned to about 29-MHz. However, because it has a much lower Q than the crystal, it has no effect on oscillator frequency. The frequency of the VCO is controlled by the collector tuning which includes a varicap diode. The oscillator frequency can be varied over a 1-MHz range, with a zero to +12V change in control voltage on the varicap. Two adjustments are provided for the initial frequency set-up of the VCO. The collector inductance adjusts the center frequency of the VCO to 31 MHz in

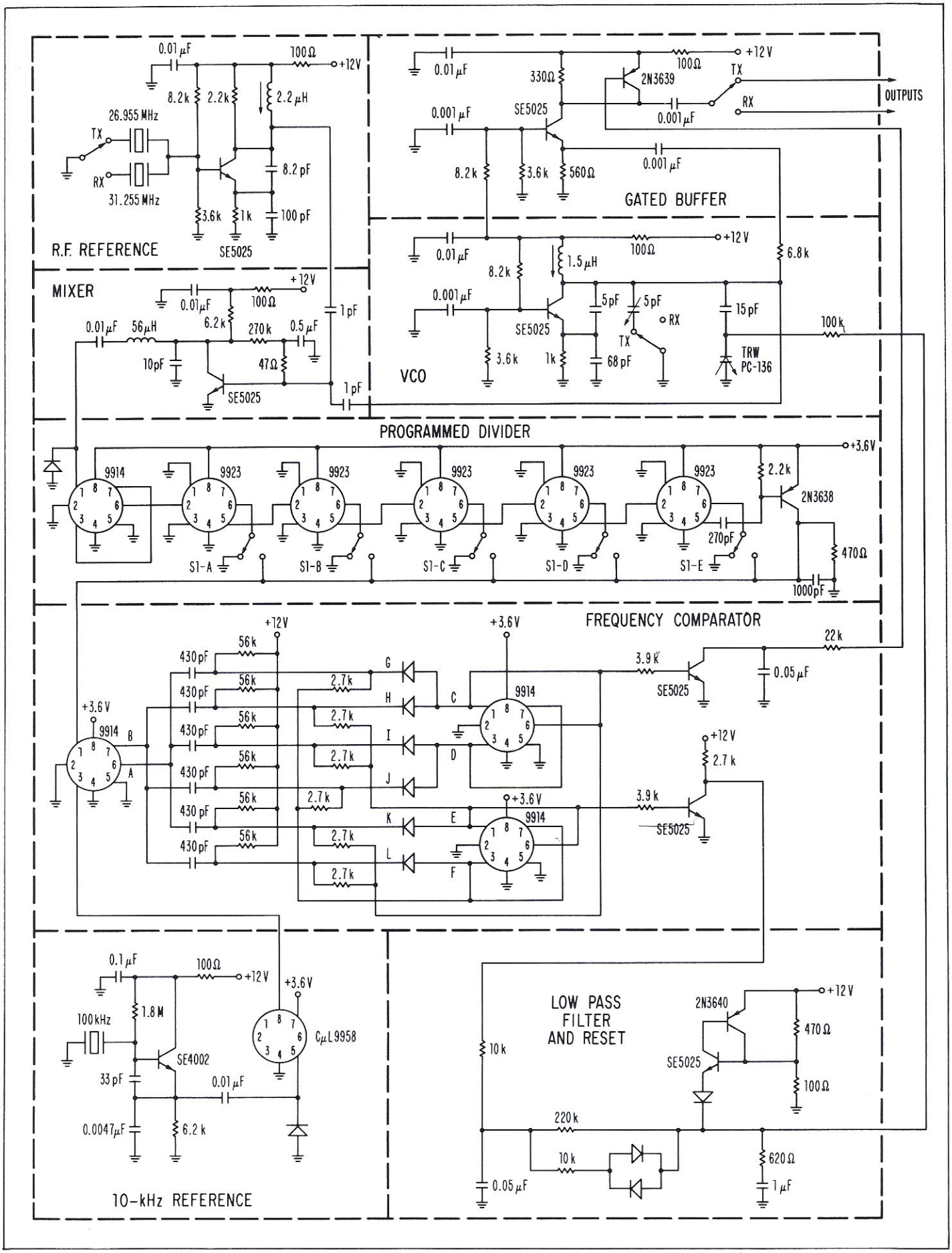

Fig. 4. Frequency synthesizer.

TABLE I

CITIZENS BAND TRANCEIVER FREQUENCIES - SYNTHESIZER DIVIDER PROGRAM.

CHANNEL	TRANSMIT FREQ. (MHz)	L.O. FREQ. (4.3 MHz IF) (MHz)	DIVIDER PROGRAM (÷ by)	POSITION OF SWITCH S1 (× - CLOSED)				
				A	B	C	D	E
1	26.965	31.265	1	×	×	×	×	×
2	26.975	31.275	2		×	×	×	×
3	26.985	31.285	3	×		×	×	×
—	—	—	—	—	—	—	—	—
4	27.005	31.305	5	×	×		×	×
5	27.015	31.315	6		×		×	×
6	27.025	31.325	7	×			×	×
7	27.035	31.335	8				×	×
—	—	—	—	—	—	—	—	—
8	27.055	31.355	10		×	×		×
9	27.065	31.365	11	×		×		×
10	27.075	31.375	12			×		×
11	27.085	31.385	13	×	×			×
—	—	—	—	—	—	—	—	—
12	27.105	31.405	15	×				×
13	27.115	31.415	16					×
14	27.125	31.425	17	×	×	×	×	
15	27.135	31.435	18		×	×	×	
—	—	—	—	—	—	—	—	—
16	27.155	31.455	20			×	×	
17	27.165	31.465	21	×	×		×	
18	27.175	31.475	22		×		×	
19	27.185	31.485	23	×			×	
—	—	—	—					
20	27.205	31.505	25	×	×	×		
21	27.215	31.515	26		×	×		
22	27.225	31.525	27	×		×		
—	—		—	—	—	—	—	—
—	—		—	—	—	—	—	—
23	27.255	31.555	30		×			

receive operation. In transmit, the variable capacitor is switched in and adjusted for an oscillator center frequency of 27 MHz.

The outputs of the two RF oscillators are capacitively coupled into the base of the mixer transistor, SE5025. The non-linear characteristics of the base-emitter junction produces a difference-frequency component in the collector which is fed through a low-pass filter to the programmable divider. Higher frequency components are attenuated.

The difference-frequency input signal to the divider is amplified and shaped in a low-power RTμL 9914 dual-gate element. This signal then drives the first of the five 9923 JK flip-flop elements. The output from the last of the five flip-flop is differentiated and fed to a PNP buffer transistor. Clock inputs to the 9923's operate each element as a normal flip-flop unless a coincident pulse from the buffer output is fed back to the element through its associated switch for reset.

The switch combinations shown in Table 1 program the divider from divide-by-1 through divide-by-30 with certain indicated skips. Although the programming is done with five separate switches, these switching combinations could be achieved with a single, 23-position, multisection channel selector switch.

The two inputs to the comparator -- the tachometer signal from the divider and the 10-KHz reference signal-- are shaped by the first 9914 dual-gate element. The outputs are differentiated in the RC networks. These pulses, fed through the diode gates, selectively trigger the other two 9914 elements which are connected as flip-flops. Operation of the circuit is most easily understood by studying Fig. 5, which shows various wave forms within the circuit for a tachometer input. This tachometer input, in time, varies in frequency from below to above the reference (standard) input.

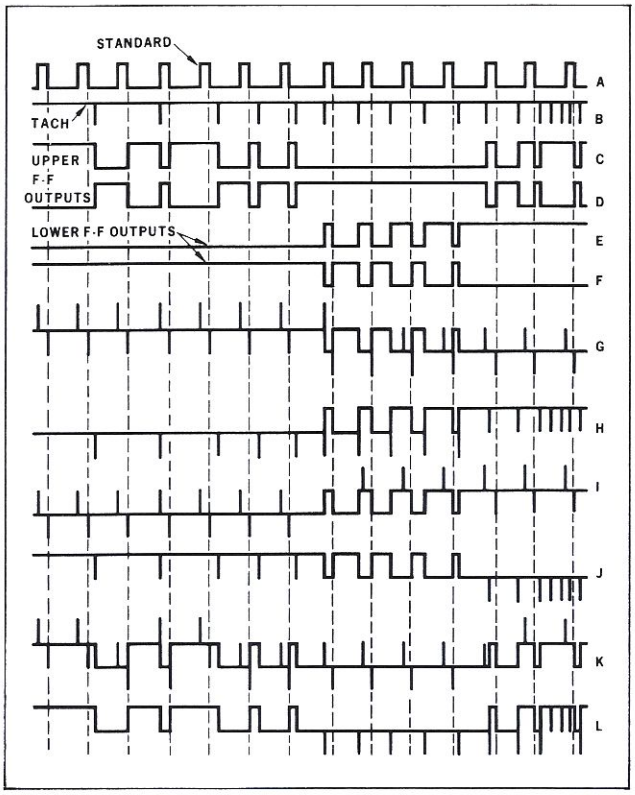

Fig. 5. Frequency comparator waveforms.

Frequency and phase information is taken from the lower flip-flop through a high-level transistor switch (SE5025). The upper flip-flop drives another transistor (SE5025) which, in turn, develops a gate voltage when the tachometer is not locked to the standard frequency. The gate voltage drives the buffer stage PNP transistor (2N3639) into saturation, which blocks the output of the common-base buffer transistor (SE5025).

The frequency and phase information output of the comparator is fed to a dual time constant, phase-compensated, low-pass filter. The back-to-back diodes speed up the time required for frequency locking of the automatic phase-controlled loop, but they do not conduct once the phase stability is established in the system.

The reset transistors (SE5025 and 2N3640) conduct if the filtered output falls to about 1 volt. Both transistors then saturate and charge the filter capacitors to the supply voltage before they are released.

The 10-KHz reference signal is taken from a CμL 9958 decade counter which is driven directly from a 100-KHz crystal-controlled, transistor oscillator (SE4002).

CONCLUSION

The 46 frequencies required for an all-channel citizens' band transceiver have been synthesized in a circuit which uses only three crystals. The accuracy of these synthesized frequencies depends entirely on the accuracy of the crystal-controlled, reference oscillators.

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